

Space Technology

Game Changing Development

Low Cost Upper Stage-Class Propulsion (LCUSP)

Overview

NASA is making space exploration more affordable and viable by developing and utilizing innovative manufacturing technologies. Technology development efforts at NASA in propulsion are committed to continuous innovation of design and manufacturing technologies for rocket engines in order to reduce the cost of NASA's journey to Mars. The Low Cost Upper Stage-Class Propulsion (LCUSP) effort will develop and utilize emerging Additive Manufacturing (AM) to significantly reduce the development time and cost for complex rocket propulsion hardware.

Benefit of Additive Manufacturing (3-D Printing)

Current rocket propulsion manufacturing techniques are costly and have lengthy development times. In order to fabricate rocket engines, numerous complex parts made of different materials are assembled in a way that allow the propellant to collect heat at the right places to drive the turbopump and simultaneously keep the thrust chamber from melting. The heat conditioned fuel and oxidizer come together and burn inside the

combustion chamber to provide thrust. The efforts to make multiple parts precisely fit together and not leak after experiencing cryogenic temperatures on one-side and combustion temperatures on the other is quite challenging.

Additive manufacturing has the potential to significantly reduce the time and cost of making rocket parts like the copper liner and Nickel-alloy jackets found in rocket combustion chambers where super-cold cryogenic propellants are heated and mixed to the extreme temperatures needed to propel rockets in space. The Selective Laser Melting (SLM) machine fuses 8,255 layers of copper powder to make a section of the chamber in 10 days. Machining an equivalent part and assembling it with welding and brazing techniques could take months to accomplish with potential failures or leaks that could require fixes. The design process is also enhanced since it does not require the 3D model to be converted to 2-D drawings. The design and fabrication process can be sped up and improved with fewer errors to be accomplished in weeks instead of months.



NASA engineers used 3-D printing to make the first full-scale copper engine part, a combustion chamber liner that operates at extreme temperatures and pressures. Structured light scanning, seen on the computer screen, helped verify that the part was built as it was designed.

Project Description

The LCUSP project focuses on two manufacturing processes. The first process takes place at Marshall Space Flight Center and will enable complex coolant passages to be directly printed using SLM 3-D printing technology out of GRCop-84 powder — a copper alloy developed by the Glenn Research Center. GRCop-84 is an alloy that provides the best property of heat conduction but also has higher strength material properties. The GRCop-84 powder was procured from Allegheny Technologies Incorporated.

The second process will utilize the E-Beam Free Form Fabrication (EBF3) Technology under development by the Langley Research Center to be to deposit a Nickel-alloy structural jacket to the GRCop-84 liner. These processes enable previously unachievable design features that will be demonstrated by fabrication of chamber and nozzle test articles. The goal of these process and design developments is to enable a repeatable process that industry can adopt to manufacture engine parts with advanced designs quickly and reliably.

Later in 2015, the engine combustion chamber component will be hot-fire tested at Marshall Space Flight Center to determine the engine performance under extreme temperatures and pressures on the test stand. In 2016, the tested combustion chamber will be integrated into a 25,000-pound force engine test bed simulating an entire rocket thrust chamber assembly and will advance this 3-D manufacturing technology ready for application toward of a flight engine.

AM technologies are maturing rapidly and appear to be a viable option to mitigate production time and cost. Although additive manufacturing is currently being used for other industries, rocket specific materials and applications are not widely available. The extreme conditions and stringent test requirements for high value components and human-rated flight systems call for a different level of materials and supporting characterization than typical AM applications. Compared to traditional manufacturing capabilities like casting, forging, and rolling, the datasets on AM-produced materials are rare. With limited materials characterized for AM in NASA's particular applications, MSFC and GRC will perform extensive analysis and materials characterization to help validate the 3-D printing processing parameters and ensure build quality. Material properties will be measured and collected; and processes will be improved



Full aft and forward chamber segment development units printed with GRCop-84 demonstrating the ability to print features required for thrust chamber.

which will become highly useful to industry applications in unpredictable, productive, and profitable ways. This data will be added to information already collected on 3-D printed parts made out of steel and other materials. All data will be made available to American manufacturers to increase U.S. industrial competitiveness. LCUSP presents an opportunity to develop and demonstrate a process that can infuse these technologies into industry, build competition and drive down costs of future engines.

The Game Changing Development (GCD) program investigates ideas and approaches that could solve significant technological problems and revolutionize future space endeavors. GCD projects develop technologies through component and subsystem testing on Earth to prepare them for future use in space. GCD is part of NASA's Space Technology Mission Directorate.

For more information about GCD, please visit <http://gameon.nasa.gov>

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